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The holoplankton of the Santa Catarina coast, southern Brazil

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ABSTRACT

This paper presents information from different sampling surveys carried out along the Santa Catarina coast in order to outline the biogeographical characteristics of the zooplankton in this region and identify species or groups of species with potential use as bioindicators. Based on a checklist of species of the zooplankton community in the state, it was observed that, in the warmer months of the year, the fauna is similar to that of the states of Paraná and São Paulo (e.g. *Creseis virgula* f. *virgula*, *Penilia avirostris*; *Acartia lilljeborgi* and *Oithona oswaldocruzi*), while in the colder months there are coastal representatives of the fauna of Rio Grande do Sul (e.g. *Acartia tonsa*). However, the zooplankton consists predominantly of warm water species for most of the year, which is typical of Tropical Shelf Waters. Various species of zooplankton can be used as hydrological indicators, enabling a distinction to be made between coastal waters which are influenced by continental inputs (e.g. *Paracalanus quasimodo* and *Parvocalanus crassirostris*), common in the north of the state, and processes of upwelling (e.g. *Podon intermedius*) and the influence of the Subtropical Shelf Front (e.g. *Pleopis polyphemoides*), coming from the south. The different environments investigated present a zooplankton abundance that depends on the influence of continental inputs and the possibility of their retaining and contribution for the coastal enrichment, which varies seasonally.

Key words: bioindicators, checklist, coastal species, water mass, coastal environments, biogeography.

INTRODUCTION

Zooplankton comprises groups of organisms commonly used as biological indicators, due to its short life cycle, high sensitivity, and abundance in aquatic ecosystems (Omori and Ikeda 1984). The knowledge on this community is vitally important in any type of environmental impact study for the installation and operation of enterprises in the coastal zone. Some zooplanktonic organisms are considered good hydrological indicators (Boltovskoy 1981), enabling the identification of different sources of water inputs that comprise the dynamic of an area.

In ecological terms, the knowledge on the zooplankton community provides information about the trophic situation of the system based on the characterization of the size structure of its constituents, as well as the feeding habits of different dominant species in the community (Parsons et al. 1984). Besides its importance in the pelagic trophic chain as a point of connection between the primary producers and the higher levels, this community presents many larvae of important fishing resources of commercial interest, such as crustaceans, decapods, molluscs and fish.

There is a lack of information concerning the zooplankton community of the Santa Catarina coast, which has been highlighted in major review works on the subject presented by Valentin et al. (1994), Brandini et al. (1997) and Lopes (2007). This lack of information is reinforced by the lack of access to data published in scientific congresses, or data generated by large oceanographic campaigns that include the continental shelf of this state. However, disperse information, both published and unpublished, can enable conclusions to be

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drawn on the biogeographical characteristics of the Santa Catarina coast, compared with other areas that have been more exhaustively investigated to the north and south of the state, such as São Paulo, Paraná and Rio Grande do Sul.

Therefore, drawing up a checklist of species recorded in a region enables, among other things, the establishment of the limits of geographical distribution of the species, comparison and confirmation of the existence of similarities among coastal regions, evaluation of the existence of species that indicate impacts and oceanographic conditions, and the establishment of key species in the use of monitoring of large-scale alterations, invasive species and test organisms applied to ecotoxicology.

STUDY AREA

The continental shelf of the state of Santa Catarina is located mainly within the Southeast Brazilian Continental Shelf (northern portion), though part of it lies on the Southern Brazilian Continental Shelf (southern portion), with its dividing point occurring at Santa Marta Cape (Hille et al. 2008) (Fig. 1).

The hydrological conditions of the Santa Catarina coast have been studied by Carvalho et al. (1998) and Hille et al. (2008), who highlight that the north coast is heavily influenced by continental inputs. On the south coast of the state, the phenomena of upwelling in summer and the influence of the plume from the Plata River and Sub-Antarctic Water (Subtropical Shelf Front) in winter (Piola et al. 2000) are key oceanographic processes that occur at Santa Marta Grande Cape. According to B.M. Castro Filho, unpublished data, Miranda (1982), Piola et al. (2000, 2005), Schettini et al. (2005) and Hille et al. (2008), the water masses occurring on the shelf are the Tropical Water (TW) of the Brazilian Current, with temperatures over 20°C and salinity higher than 36.4, and the South Atlantic Central Water (SACW), characterized by temperatures below 20°C and salinity ranging from 36.4 to 34.5. The latter lies at greater depths and is responsible for strong thermal gradients in the water column, indicating processes of upwelling on the continental shelf (Miranda 1982).

The Coastal or Shelf Water is the result of continental inputs on the TW and SACW. Finally, the Sub-Antarctic Shelf Water, which originates from the mixing of the Malvinas Current with the discharge from the Prata River and Patos Lagoon, borders the south coast of Brazil as far as the region of Santa Marta Grande Cape in winter (Piola et al. 2000).

The north of Santa Catarina is influenced by various river systems, which change the concentrations of nutrients and the biological processes. These include the Itapocu, Itajaí-açu, Tijucas and Tubarão Rivers. In general, a decrease in salinity and an increase in concentrations of surface nutrients are seen in the areas around the river mouths of these systems (Bellotto et al. 1996, Schettini et al. 1998). The continental inputs, indented geography, and presence of numerous islands, together make up a coastline with various sub-environments, each of which has its own oceanographic features and biological species.

The environments for which more technical and scientific information have been gathered in recent years are shown in Figure 1 and Table I, and are mainly located to the north of the state of Santa Catarina:

1) The Babitonga Bay, on the north coast of Santa Catarina, is an environment which is characterized by an extensive formation of mangroves with continental inputs from three main rivers: The Palmital, the Cubatão and the Cachoeira Rivers (Kuroshima and Bellotto 1998, Cunha et al. 1999).

2) The Armação do Itapocoroy Bay, has been the object of intensive studies in recent years, as it is currently the largest mussel cultivation area in the state. According to Schettini et al. (1999), the waters of the Armação do Itapocoroy Bay are typically comprised of coastal waters (salinity lower than 34), with a seasonal temperature ranging from 19°C to 28°C. Both the salinity and the load of material in suspension are directly influenced by the Itajaí-açu River (Carvalho et al. 1998, Resgalla Jr and Schettini 2006), which has a plume of brackish water flowing northwards from the river mouth.

3) Navegantes Beach – a dissipative beach, heavily influenced by the inputs from the Itajaí-açu River mouth (Rörig et al. 1997).

4) Itajaí-açu River estuary and adjacent coastal region – the Itajaí-açu River basin is the largest river basin,

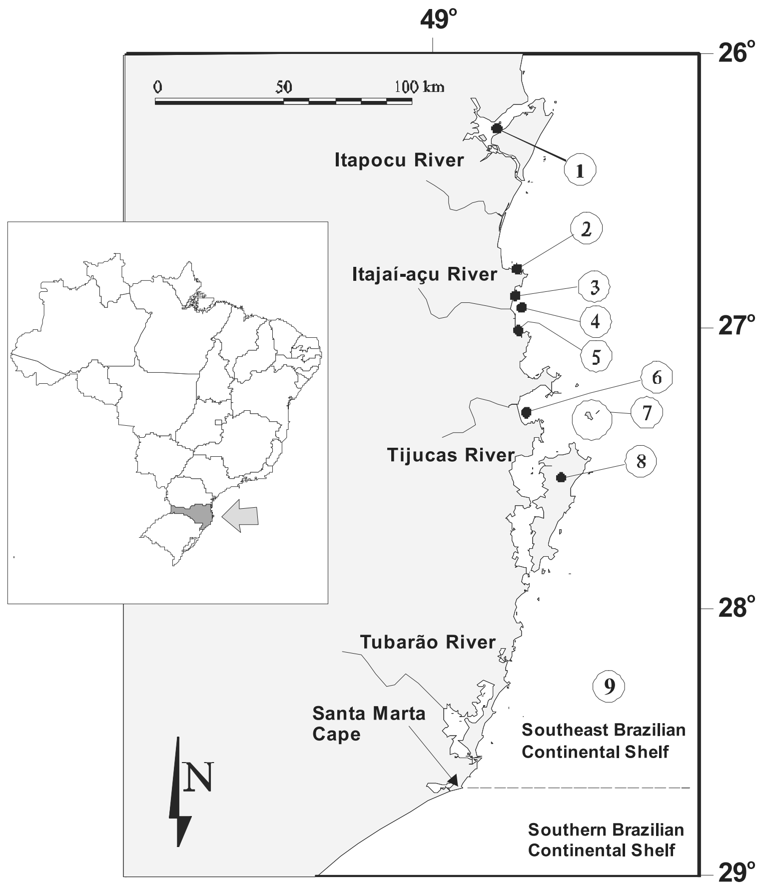

Fig. 1 – Location of the state of Santa Catarina (25°57′41″–29°23′55″S and 48°19′37″–53°50′00″W) in the south of Brazil, and coastal environments in which the samplings of zooplankton were collected (Table I). It also shows the identification of the rivers, and division of the continental shelf at Santa Marta Cape.

with 15,111 km^2, which corresponds to 25% of the total area of the state. The influence of salinity, which characterizes the estuary itself, is observed 30 Km upstream from the river mouth due to the amplitude of the spring tide of 1.2 m and the pluviometric regimes (Schettini et al. 1998, Rörig 2005).

5) The Camboriú Bay highlights the influence of the Camboriú River on the salinity of the waters in the southern portion (F. Morelli, unpublished data, Schettini and Carvalho 1998).

6) The Zimbros Bay is influenced by the action of waves and by an extensive sedimentary plain, produced by inputs from the Tijucas River (Schettini and Carvalho 1998).

7) The Arvoredo Marine Biological Reserve is located 11 km to the north of Santa Catarina Island (Florianópolis), and is comprised of four islands influenced by the Brazilian Current and the Subtropical Shelf Front. It is characterized by a diversity of transitional areas (Rocha et al. 2005).

8) Santa Catarina Island, in the municipality of Florianópolis, has various environments that have been historically sampled in relation to their plankton community, particularly Conceição Lagoon, an estuarine environment whose studies date back to 1982 (Knoppers et al. 1984, Odebrecht 1988).

9) Unpublished records of zooplankton species occurring in the beaches to the south of the state (municipality of Garopaba), as well as samplings in oil drilling platforms, also make up the sampling grid for the Santa Catarina external continental shelf and oceanic area.

TABLE I
Identification of the samplings carried out on the Santa Catarina coast by environment (according to Fig. 1), type of study, number of samples and collection date.

Area	Environment	Study	Number of samples	Date
1	Babitonga Bay	Schettini et al. (2002)	10	03/1999
		Schettini et al. (2002)	02	11/2000
		This paper	07	03/2006
		This paper	42	09/2006-07/2007
2	Itapocoroy Bay	Resgalla Jr and Veado (2006), R.D. Nunes, unpublished data	120	09/2002-09/2003
3	Navegantes Beach	Rörig et al. (1997)	02	10/1995
4	Itajaí-açu River and the adjacent coastal region	Schettini et al. (1998), Rörig et al. (2003)	11	03/1996
		Resgalla Jr et al. (2008)	126	11/2002-12/2003
		L.D.V. Veado, unpublished data	45	12/2005-05/2007
		This paper	14	12/2003
		L.D.V. Veado, unpublished data	95	06/2005-01/2007
5	Balneário Camboriú Bay	This paper	10	04/2007
6	Zimbros Bay	This paper	32	02/2007, 03/2007 and 07/2007
7	Arvoredo Marine Biological Reserve	L.M. Fernandes, unpublished data	15	11/1995
		Resgalla Jr et al. (2004)	12	12/1998
8	Santa Catarina Island	Resgalla Jr (2001), Veado and Resgalla Jr (2005), D.C. Mori, unpublished data	150	10/1996-10/2006
		This paper	24	02/2007, 03/2007 and 07/2007
9	Oceanic region	This paper	06	03/2003 and 06/2003
	South of the state	This paper	03	04/1997 and 2003

METHODOLOGY

Data were compiled on the density and specific composition of the zooplankton community and obtained in different coastal environments of the Santa Catarina coast and in different seasons of the year using different sampling equipment, but always in quantitative samplings. The samplings in estuaries and bays were carried out using WP-2 nets with a 200μm mesh size and 30 cm opening diameter. For the beach sampling, conical nets were used, with a 300μm mesh size and 50 cm opening diameter, and for shelf areas the standard WP-2 net was used, with a 200μm mesh size and 60 cm opening diameter. All the trawls were carried out using a flowmeter to estimate the volume of filtered water. Abiotic data for water temperature and salinity were obtained in all samplings. Information from the samples is presented in Table I and summarized for each environment.

Besides the new data for zooplankton, the publications used in this work referring to the coastal region were as follows: Schettini et al. (2002) to the Babitonga Bay; Duarte (1999), Resgalla Jr and Veado (2006) and R.D. Nunes, unpublished data to the Armação do Itapocoroy Bay; Rörig et al. (1997) to Navegantes Beach; Schettini et al. (1998, 2005), Rörig et al. (2003), Resgalla Jr et al. (2008) and L.D.V. Veado, unpublished data to the Itajaí-açu River estuary and adjacent coastal region; M.J. Novaes, unpublished data to Camboriú Bay; L.M. Fernandes, unpublished data and Resgalla Jr et al. (2004) to the Arvoredo Marine Biological Reserve; and Resgalla Jr (2001), Veado and Resgalla Jr (2005) and D.C. Mori unpublished data to the South Bay (Santa Catarina Island).

For the area of the external shelf, there are works on zooplankton groups carried out based on samples of major scientific cruises, such as the *Projeto Uso e Exploração Racional do Ambiente Marinho* (Rational Use and Exploitation of the Marine Environment) (24°–29°S) carried out in 1976 (M.R. Oliveira, unpublished data), CONVERSUT – Estudo da Área de Convergência Sub-tropical (Study of the Sub-tropical Area of Convergence) (28°–34°S) carried out from 1977 to 1981 (M.J. Coelho, unpublished data), SUESTE I (24°–29°S) carried out in 1982 (W.J.A. Amaral, unpublished data), SARP – Sardine/Anchovy Recruitment Project (28°S) carried out in 1989, Projeto Sardinha 2 (23°–28°S) carried out in 1993 (Campos 2004), and ECOSAR 2 – Prospecção e Avaliação de Biomassa do Estoque de Sardinha, na Costa Sudeste, por Métodos Hidroacústicos (Prospecting and Evaluation of the Sardine Stock Biomass on the Southeast Coast, by Hydroacoustic Methods) (22°–28°S) carried out in 1995 (E. Muxagata, unpublished data).

Additional information for Cnidaria was obtained in the works of Resgalla Jr et al. (2005) and Rossetto et al. (2007) relating to records of jellyfish accidents on the main beaches of the state.

A checklist of zooplankton species was drawn up, and comparisons were made with the fauna of the coastal environments to the north, São Paulo (C.L. De La Rocha, unpublished data) and Paraná (Montú 1987, Montú and Cordeiro 1988), and to the south, in Rio Grande do Sul (Montú 1980, Montú and Gloeden 1986, E. Muxagata, unpublished data), in order to determine the limits of distribution of species and establish the similarity between the areas. The compilation works of the plankton community for the Brazilian coast, carried out by Boltovskoy (1981, 1999), Valentin et al. (1994), Brandini et al. (1997), Lopes et al. (2006) and Lopes (2007), were used to help to determine the similarities observed.

The check list for this work did not include the meroplankton occurring on the Santa Catarina coast, which can be obtained in works with the larvae of Cirripedia, by Severino and Resgalla Jr (2005), larvae of Decapoda, by Koettker and Freire (2006), and various works with ictioplankton (M.D.P. Costa, unpublished data, Souza-Conceição 2008, Macedo-Soares et al. 2009, T. Rutkowski, unpublished data, T. Rutkowski, unpublished data). A complete list of freshwater zooplankton species occurring in the estuary of the Itajaí-açu River can be seen in L.D.V. Veado unpublished data.

For the classification of species by type of water of occurrence, TS-P (Temperature, Salinity and Plankton) diagrams were created for the main coastal environments of Santa Catarina involving all the sampling periods and the records of species observed, thereby delimiting the representative groups of the coastal and oceanic areas, as well as the warm and cold waters.

RESULTS AND DISCUSSION

The marine zooplankton of the Santa Catarina coast is highly diverse, comprising 21 main groups and 150 *taxa* distributed by family, genus, species and stages of development (Table II). Copepoda had the highest taxonomic diversity, which was represented by 52 taxa on this coast.

Dominant Environments and Species

For the external continental shelf region, the zooplankton community is highly diverse. However, this diversity is less than that observed by M.J. Coelho, unpublished data and Resgalla Jr and Montú (1995) for Chaetognatha, suggesting a predominance of the Tropical Water from the Brazilian Current, with salinities higher than 33 and temperatures higher than 20°C, and a certain distance from the western border of the Subtropical Convergence Zone. This characteristic is confirmed by the predominance of species like the Copepoda *Acartia negligens*, the Cladocera *Evadne spinifera*, and the Chaetognatha *Sagitta serratodentata*. Despite the presence of oceanic representatives of warm waters, coastal species typical of salinities lower than 31, such as *Acartia lilljeborgi* and *Penilia avirostris*, are common on the external shelf, but in low densities (Fig. 2).

For the coastal zone, the zooplankton is dominated by Copepoda, the most representative of the group

TABLE II

***Taxa* of zooplankton identified in different areas (according to the caption of Fig. 1) of the Santa Catarina coast.**

Groups/Species	Environment	Groups/Species	Environment
Cnidaria		Copepoda	
Polyps	4, 8	Limnic copepoda	1, 4
Hidromedusae	1, 3, 4, 8, 9	*Acartia lilljeborgi* Giesbrecht, 1889	1, 2, 3, 4, 8
Liriope tetraphylla (Chamisso and Eysenhardt, 1821)	4, 8	*Acartia negligens* Dana, 1849	9
Calicophorae	3, 4, 8, 9	*Acartia* sp	8, 9
Physalia physalis (Linnaeus, 1758)	2, 7, 9	*Acartia tonsa* Dana, 1849	1, 8
Semaeostomeae	1, 2, 5, 9	Calanidae	4, 8, 9
Cubozoa	2	*Calanopia americana* Dahl, 1894	8
Linuche unguiculata (Schwartz, 1788)	5	Calocalanidae	4
Chiropsalmus quadrumanus (Müller, 1859)	2	*Calocalanus* sp	8, 9
Olindias sambaquiensis Muller, 1861	9	*Centropages velificatus* (Oliveira, 1947)	4, 8
Lychnorhiza lucerna Haeckel, 1880	9	Centropagidae	9
Tamoya haplonema (Müller, 1859)	2	*Clytemnestra rostrata* (Brady, 1883)	4, 9
Pelagia noctiluca (Forsskal, 1775)	9	*Copilia mirabilis* Dana, 1852	9
		Corycaeus sp	3, 4, 8, 9
		Corycaeus speciosus Dana, 1849	9
Ctenophorae		*Eucalanus cornutus* Sars, 1912	9
Beroe sp	1, 8	*Eucalanus crassus* Giesbrecht, 1888	9
		Eucalanus pileatus Giesbrecht, 1888	4, 8
Mollusca		*Eucalanus sewelli* Dana, 1849	9
Bivalvia (veliger)	4, 8, 9	*Eucalanus* sp	9
Gastropoda (veliger)	1, 4, 8, 9	*Euterpina acutifrons* (Brian, 1921)	1, 4, 8
Creseis virgula f. *virgula* (Rang, 1828)	4, 8, 9	*Farranula gracilis* (Dana, 1849)	9
Limacina sp	4	*Farranulla* sp	4, 9
Limacina inflata (d'Orbigny, 1836)	4, 9	*Hemicyclops thalassius* Vervoort and Ramires, 1966	8
Limacina trochiformis (d'Orbigny, 1836)	8, 9	*Labidocera fluviatilis* Dahl, 1894	1, 4
Janthina sp	2	*Macrosetella gracilis* (Dana, 1847)	4, 8, 9
Atlanta sp	8, 9	*Mesocyclops* sp	1
Pterotracheidae	9	*Microsetella rosea* (Dana, 1849)	9
Cavolinia inflexa f. *imitans* (Pfeffer, 1880)	9	*Monstrilla rogusa* Davis, 1947	2
		Monstrilla sp	2
		Monstrilloida	2, 8
Annelida		*Oithona oswaldocruzi* Oliveira, 1947	1, 4, 8
Oligochaeta	1	*Oithona ovalis* Herbst, 1955	4
Polychaeta (larvae	1, 4, 8	*Oithona plumifera* Baird, 1843	3, 4, 8
Polychaeta (planktonic)	8	*Oithona* sp	4, 8, 9
		Oncaea sp	4, 9
Cladocera		*Oncaea venusta* Philippi, 1843	8
Diaphanosoma sp	1	*Paracalanus nanus* (Sars, 1907)	8
Ilyocryptus spiniger Herrick, 1884	1, 4	*Paracalanus quasimodo* Bowman, 1971	8
Moina minuta Hansen, 1899	1, 4	*Paracalanus* sp	1, 3, 4, 8, 9
Daphinia sp	1	*Parvocalanus crassirostris* (Dahl, 1894)	8
Ceriodaphinia sp	1	*Phaenna spinifera* Claus, 1863	8, 9
Penilia avirostris Dana, 1852	3, 4, 7, 8, 9	Pontellidae	4, 8, 9
Pseudevadne tergestina (Claus, 1877)	3, 4, 7, 8, 9	Pseudocalanidade	3, 4
Evadne spinifera Müller, 1868	1, 4, 7, 9	*Pseudodiaptomus richardi* (Dahl, 1894)	1, 3, 4, 8
Pleopis polyphemoides (Leuckart,1859)	2, 4, 8	*Rhincalanus nasutus* Giesbrecht 1888	9
Pleopis schmackeri (Poppe, 1889)	4, 7	*Sapphirina stellata* Giesbrecht, 1891	9
Podon intermedius Lilljeborg, 1853	4, 7	Scolecithricidae	9
		Temora sp	1, 4, 8, 9
		Temora stylifera (Dana, 1849)	3, 4, 8
Ostracoda		*Temora turbinata* (Dana, 1849)	4, 8
Benthonic	8, 4, 3	*Thaumaleus longispinosum* (Bourne, 1890)	2
Planktonic	9	*Thaumaleus* sp (Monstrilloida)	2

TABLE II (continuation)

Groups/Species	Environment	Groups/Species	Environment
Cirripedia		Chaetognatha	
Nauplii	1, 2, 3, 4, 8	*Sagitta* sp	8, 9
Cypris	1, 2, 4, 8	*Krohnitta pacifica* (Aida, 1897)	4, 7
		Krohnitta subtilis (Grassi, 1881)	9
Stomatopoda (larvae)	7, 8	*Pterosagitta draco* (Krohn, 1853)	9
		Sagitta enflata Grassi, 1881	3, 4, 7, 8, 9
Mysida		*Sagitta hexaptera* d'Orbigny, 1843	9
Metamysidopsis elongata atlantica (Bacescu, 1968)	3, 5, 8	*Sagitta hispida* Conant, 1895	4, 7, 8
Promysis atlantica Tattersall, 1923	7, 8	*Sagitta minima* Grassi, 1881	9
		Sagitta serratodentata Krohn, 1853	9
Isopoda	1, 3, 8, 9	*Sagitta friderici* (=*tenuis*) (Ritter-Zahony, 1911)	1, 4, 7, 8, 9
Amphipoda		Larvacea	
Caprellidae	8	*Oikopleura* sp	3, 4, 8
Gammaridea	3, 4, 8	*Oikopleura dioica* (Fol, 1872)	1, 8
Hiperiidea	4, 8, 9	*Oikopleura parva* Lohmann, 1896	8
		Oikopleura intermedia Lohmann, 1896	9
		Oikopleura fusiformis Fol, 1872	9
Euphausiacea		*Oikopleura longicauda* (Vogt, 1854)	9
Metanauplius	9	*Oikopleura rufescens* Fol, 1872	9
Caliptopis	4, 7, 9	*Oikopleura albicans* (Leuckart, 1854)	9
		Oikopleura cornutogastra Aida, 1907	9
		Fritillaria pellucida (Busch, 1851)	9
Decapoda		*Fritillaria formica* Fol, 1872	9
Egg	8	*Fritillaria sargassi* Lohmann, 1896	9
Nauplii	8	*Fritillaria haplostoma* Fol, 1872	9
Protozoea	4, 8, 9	*Fritillaria tenella* Lohmann, 1896	9
Mysis	1, 4, 8, 9	*Tectillaria fertilis* (Lohmann, 1896)	9
Zoea	1, 3, 4, 8, 9		
Megalopa	1, 4, 9	Ascidiacea	8
Palinura (decapodito)	8		
Penaeus sp (decapodito)	7, 8	Lophophorata	8
Lucifer sp	7, 8		
Lucifer faxoni Borradaile, 1915	4, 8, 9	Thaliacea	
		Doliolum nationalis Borgert, 1894	4, 7, 9
		Thalia cicar van Soest, 1973	9
Thanaidacea	1	*Thalia democratica* (Forskal, 1775)	2, 4, 7, 9
		Thalia orientalis Tokioka, 1937	9
		Pyrosoma atlanticum Péron, 1804	9
Echinodermata		*Salpa fusiformis* (Cuvier, 1804)	9
Pluteus	3, 4, 8	*Weelia cylindrica* (Cuvier, 1804)	4

being *Acartia lilljeborgi* and *Paracalanus quasimodo*, followed by the genera *Corycaeus* and *Temora*. This prevalence is provided by waters with temperatures between 20°C and 29.6°C, and salinities between 25 and 35 (Fig. 2). Other well-represented organisms are the Larvacean *Oikopleura dioica*, the Chaetognatha *Sagitta friderici* and *Sagitta enflata* and, in particular, the Cladocera *Penilia avirostris* and *Evadne tergestina*. These species are common in the Brazilian coast, and are typical of warm waters of the continental shelf under strong influence of Tropical Water of the Brazilian Current (Björnberg 1981, Ramirez 1981, Resgalla Jr and Montú 1993, 1995).

Estuarine zooplankton, typical of salinity between 5 and 30, is also dominated by Copepoda of the genus *Acartia*, presenting alternating prevalence between species of *A. lilljeborgi* and *A. tonsa* whose ecological preferences have been described by Björnberg (1981), i.e. *A. lilljeborgi* presents preferences for warmer waters (temperatures higher than 20°C), while *A. tonsa* is common

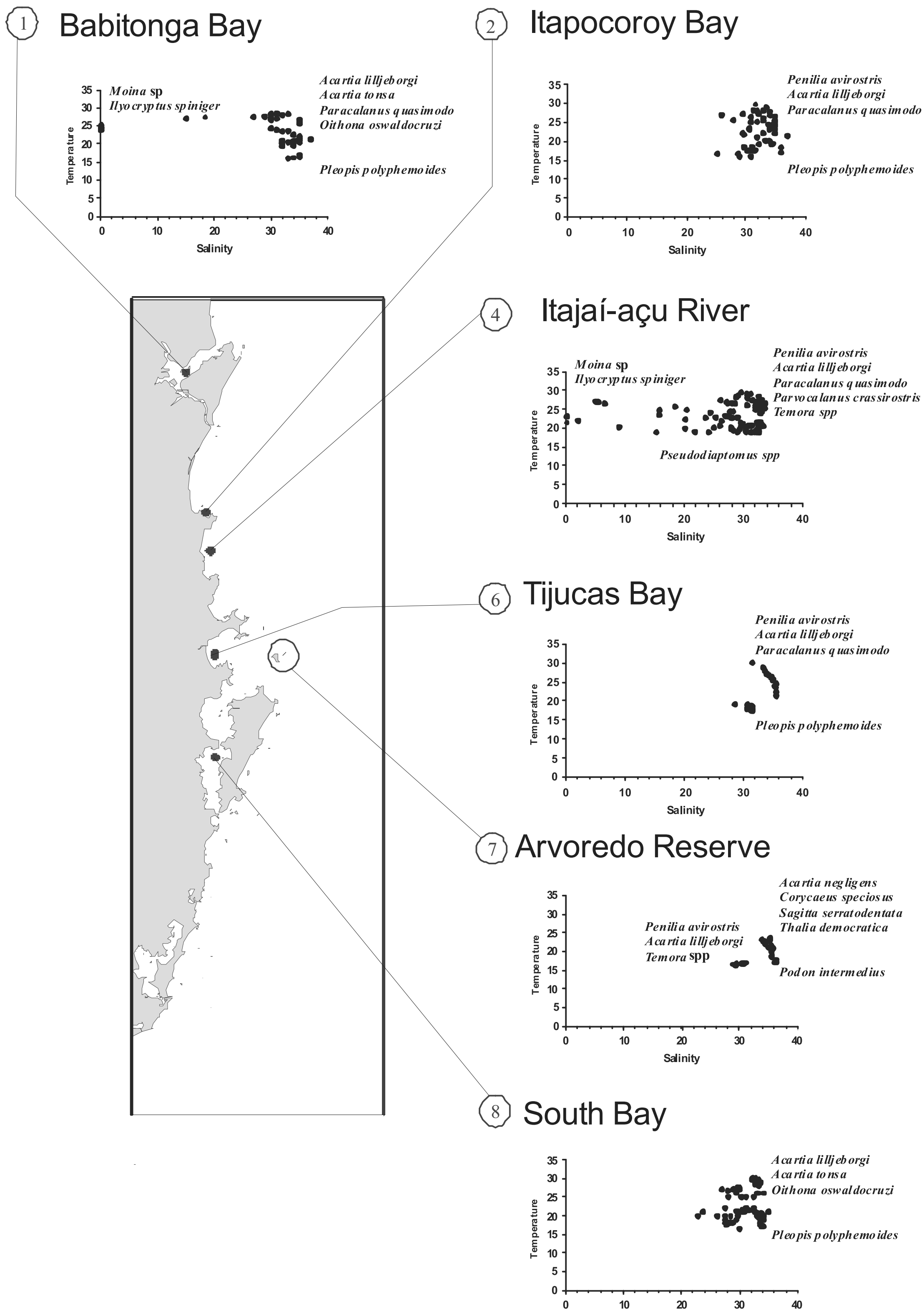

Fig. 2 – TS diagrams and main species of zooplankton organisms occurring on the Santa Catarina coast. The numbers refer to the environments described in Figure 1 and Table I.

in colder waters (temperatures lower than 20°C). In the north of the state, in the Babitonga Bay, *A. lilljeborgi* is dominant, while in the central region (the South Bay of Santa Catarina Island) and Conceição Lagoon (Odebrecht 1988), *A. tonsa* has higher densities during the spring and winter. It seems that the occurrence of *A. tonsa* depends not only on variations in salinity and temperature, but also on the characteristics of the environments covered and the availability of food in these environments (Paffenhoefer and Stearns 1988). This fact is corroborated by the absence of *A. tonsa* in the Itajaí-açu River estuary.

Other species of Copepoda also occur in significant quantities in the estuaries of Santa Catarina, including *Oithona oswaldocruzi*, *Parvocalanus crassirostris*, *Paracalanus quasimodo*, *Temora stylifera*, *T. turbinata* and *Euterpina acutifrons*, and the Chaetognath *Sagitta friderici*. The fauna of the estuarine zooplankton is very similar to that found in the estuaries of São Paulo, Paraná and Rio Grande do Sul (Table III). The difference lies in the occurrence and prevalence of species of *Acartia*, suggesting that the Santa Catarina coast is a transitional region between the fauna of the south (colder) and that of the north (warmer).

For the beach regions (Navegantes and Balneário Camboriú beaches), the similarity with the region of Rio Grande do Sul is due to the resident species of Mysidacea, which are typical of the surf zone of dissipative beaches comprised almost exclusively of *Metamysidopsis elongata atlantica* (Rörig et al. 1997, M.J. Novaes, unpublished data).

Environments and Total Density of Zooplankton

In terms of density of zooplankton, the highest values are reported in estuarine environments or coastal zones close to or influenced by inputs from the rivers (Fig. 3). The freshwater input and its mixing within the Babitonga Bay favour a higher residence time of the waters and the development of the phytoplankton community and the herbivorous zooplankton in its environment. In the Armação do Itapocoroy Bay, despite it being a relatively exposed region, the influence of the Itajaí-açu River plume is responsible for the plankton development of the area through the input of nutrients for the phytoplankton (Resgalla Jr and Schettini 2006). In the South Bay of the Santa Catarina Island, the lower dynamic of the waters and inputs from small rivers lead to the development of an abundant planktonic community.

Biomass

Data on zooplankton biomass are more limited for the area of study. For the adjacent coastal region of the mouth of the Itajaí-açu River, Schettini et al. (1998) observed a maximum of 46.92 $mg.m^{-3}$ in dry mass and high organic carbon content, indicating high biological activity in the river plume. Data for biovolume and wet mass biomass were obtained from the Arvoredo Marine Biological Reserve, and indicated high values (maximum 0.51 $mL.m^{-3}$ and 8.23 $g.m^{-3}$) related to the occurrence of the Thaliacea *Thalia democratica* (L.M. Fernandes, unpublished data, Resgalla Jr et al. 2004).

Outbreaks/Blooms

Seasonally, high densities of *Thalia democratica* and the Eutecosomata *Creseis virgula* f. *virgula* occur, normally lasting from the end of summer until the autumn. These occurrences have been highlighted by other works, particularly for Thaliacea on the coast of São Paulo (Pires-Vanin et al. 1993), Santa Catarina (L.M. Fernandes, unpublished data) and from Rio de Janeiro to Rio Grande do Sul (W.J.A. Amaral, unpublished data), highlighting their relationships with locations with higher phytoplanktonic production that may be involved with processes of localized upwelling along the coast (Resgalla Jr et al. 2001). In the Arvoredo Marine Biological Reserve, the occurrence of a higher abundance of Thaliacea was also related to the variation in concentration of the ammonicacal nitrogen in the water column (Resgalla Jr et al. 2004). It is interesting to note that both Thaliacea and Pteropoda present the same feeding strategy, i.e. they capture their food by filtering the water through the mucus, which retains small particles. This strategy makes them more efficient than other filterers and gives advantages in short processes of upwelling. These processes favor the development of a microbial loop following the death of the phytoplankton after the nutrients have been exhausted. However, these alterations in the pelagic system have still been little studied for the Brazilian coast.

TABLE III

Main representatives of the zooplankton community of different estuaries of the south and southeast regions of Brazil.

Groups	Cananéia Estuary (SP)	Paranaguá Bay (PR)	Babitonga Bay – Itajaí-açu River – South Bay – Conceição Lagoon (SC)	Patos Lagoon Estuary (RS)
Copepoda	*Acartia lilljeborgi*, *Oithona oswaldocruzi*, *Pseudodiaptomus richardi*, *Acartia tonsa*, *Parvocalanus crassirostris*	*Acartia lilljeborgi*, *Euterpina acutifrons*, *Oithona oswaldocruzi*, *Paracalanus quasimodo*, *Oithona ovalis*	*Acartia lilljeborgi*, *Acartia tonsa*, *Oithona oswaldocruzi*, *Euterpina acutifrons*, *Temora stylifera*, *Parvocalanus crassirostris*, *Paracalanus quasimodo*	*Acartia tonsa*, *Acartia lilljeborgi*, *Paracalanus quasimodo*, *Parvocalanus crassirostris*, *Euterpina acutifrons*
Myside	*Metamysisdopsis elongata atlantica*, *Promysis atlantica*, *Bwomaniella brasiliensis*	—	*Metamysisdopsis elongata atlantica*, *Promysis atlantica*	*Metamysisdopsis elongata atlantica*, *Promysis atlantica*
Chaetognatha	—	*Sagitta friderici*	*Sagitta friderici*	*Sagitta friderici*
Larvacea	—	*Oikopleura dioica*	*Oikopleura dioica*	*Oikopleura dioica*
Cladocera	—	*Penilia avirostris*	*Penilia avirostris*	—

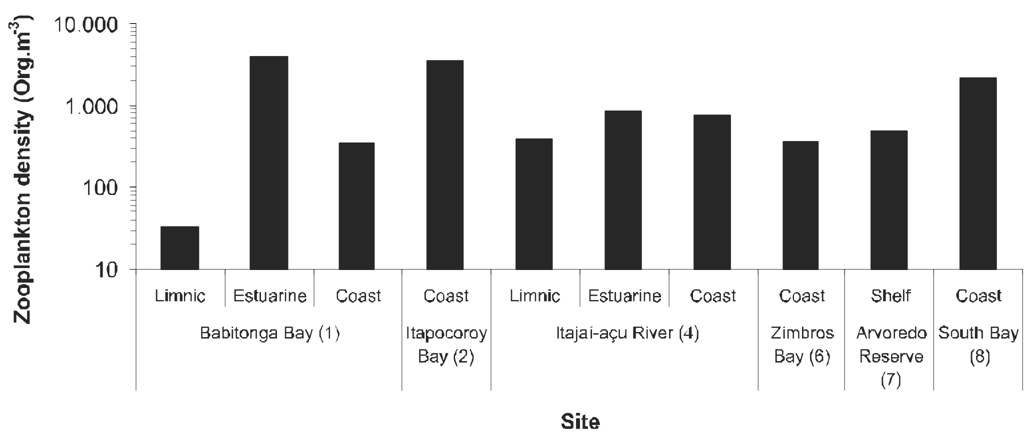

Fig. 3 – Mean of the total values of all data available for the zooplankton densities (Org.m^{-3}) in different environments and waters for the Santa Catarina coast.

INDICATORS

For other constituents of the shelf, the use of cladocera as a hydrological indicator is highlighted. *Podon intermedius* was characterized as an indicator of SACW upwelling on the continental shelf of Rio de Janeiro (Valentin 1988) and São Paulo (C.E.F. Rocha, unpublished data), and its occurrence in the region adjacent to the Itajaí-açu River mouth and the Arvoredo Marine Biological Reserve was also related to these oceanographic processes (Fernandes 1998, Schettini et al. 1998). *Pleopsis polyphemoides* has been highlighted as an indicator of the Subtropical Shelf Front (Sub-Antarctic Water under the influence of the Prata River) to Rio Grande do Sul (Resgalla Jr and Montú 1993) and Santa Catarina (Muxagata and Montú 1999). In fact, the occurrence of this species is restricted to the coldest three months of the year. However, the absence of records of *Evadne nordimanni*, a typical species of the cold coastal waters of Argentina (Ramirez 1981) and the extreme south of Brazil (Resgalla Jr and Montú 1993), may indicate a significant alteration of the coastal branch of the Sub-Antarctic Water.

Finally, the species of the zooplankton community can be classified according to their preferential habits, as well as the physical-chemical characteristics of water masses occurring in Santa Catarina (Fig. 2 and Table IV). Many species present a wider distribution, and are abundant both in estuaries and beaches in the coastal

TABLE IV
Zooplankton species by habitat and physical-chemical preferences of water occurrence.

Environment/ Water Mass	Group	Species
Beach	Cladocera	*Penilia avirostris; Pseudevadne tergestina*
	Copepoda	*Acartia lilljeborgi; Oithona plumifera; Pseudodiaptomus richardi; Temora stylifera*
	Mysidacea	*Metamysidopsis elongata atlantica*
	Chaetognatha	*Sagitta enflata; Sagitta friderici*
Estuarine	Cnidaria	*Liriope tetraphylla*
	Cladocera	*Penilia avirostris; Pseudevadne tergestina; Evadne spinifera; Pleopis polyphemoides*
	Copepoda	*Acartia lilljeborgi; Acartia tonsa; Calanopia americana; Euterpina acutifrons; Oithona oswaldocruzi; Paracalanus quasimodo; Parvocalanus crassirostris; Pseudodiaptomus richardi; Temora stylifera; Temora turbinata*
	Mysidacea	*Metamysidopsis elongata atlântica*
	Chaetognatha	*Sagitta enflata; Sagitta hispida; Sagitta friderici*
	Larvacea	*Oikopleura dioica; Oikopleura parva*
Coastal	Cnidaria	*Liriope tetraphylla*
	Mollusca	*Creseis virgula f. virgula; Janthina sp*
	Cladocera	*Penilia avirostris; Pseudevadne tergestina; Evadne spinifera; Pleopis polyphemoides; Podon intermedius; Pleopis schmackeri*
	Copepoda	*Acartia lilljeborgi; Centropages velificatus; Clytmnestra rostrata; Eucalanus pileatus; Euterpina acutifrons; Hemycyclops thalassius; Labidocera fluviatilis; Macrosetella gracilis; Oithona ovalis; Oithona plumifera; Oncaea venusta; Paracalanus quasimodo; Parvocalanus crassirostris; Paracalanus nanus; Phaenna spinifera; Pseudodiaptomus richardi; Temora stylifera; Temora turbinata*
	Mysidacea	*Promysis atlantica*
	Chaetognatha	*Krohnitta pacifica; Sagitta enflata; Sagitta hispida; Sagitta friderici*
	Larvacea	*Oikopleura dioica; Oikopleura parva*
	Thaliacea	*Doliolum nationais; Thalia democratica; Weelia cylindrica*
Oceanic	Cnidaria	*Physalia physalis*
	Mollusca	*Creseis virgula f. virgula; Limacina inflata; Limacina trochiformis; Janthina sp; Atlanta sp.; Cavolinia inflexa f. imitans*
	Cladocera	*Penilia avirostris; Pseudevadne tergestina; Evadne spinifera*
	Copepoda	*Acartia negligens; Clytmnestra rostrata; Copilia mirabilis; Corycaeus speciosus; Farranulla gracilis; Microsetella rosea; Phaenna spinifera; Rhincalanus nasutus; Sapphrina stellata*
	Chaetognatha	*Sagitta serratodentata; Sagitta minima; Krohnitta pacifica*
	Larvacea	*Tectillaria fertilis*
	Thaliacea	*Doliolum nationalis; Thalia democratica; Thalia orientalis; Salpa fusiformis; Pyrosoma atlanticum*
Warm water	Mollusca	*Creseis virgula f. virgula*
	Cladocera	*Penilia avirostris; Pseudevadne tergestina; Evadne spinifera*
	Copepoda	*Acartia lilljeborgi; Oithona oswaldocruzi*
	Thaliacea	*Doliolum nationais; Thalia democratica*
Cold water	Cladocera	*Pleopis polyphemoides; Podon intermedius*
	Copepoda	*Acartia tonsa*

region. Examples include *A. lilljeborgi*, *P. quasimodo*, *T. tubinata* and *S. friderici*, the oceanic species having more clearly defined distribution limits. However, the coastal species can be used as indicators of continental inputs in association with other more euryhalinas species, such as those of the *Pseudodiaptomus* and *Paracalanus* genera. Cold water species, which are observed in low densities in the samples despite being characterized as true indicators of water masses in the region, enable the occurrence of processes of upwelling and the influence of the Subtropical Shelf Front in the region during the winter months.

CONCLUSIONS

The zooplankton of the Santa Catarina coast has very similar characteristics to the fauna of environments of the southeast region of Brazil, where a prevalence of Tropical Shelf Water is observed (e.g. *Creseis virgula* f.

virgula, *Penilia avirostris*; *Acartia lilljeborgi* and *Oithona oswaldocruzi*). However, it presents representatives of colder waters (e.g. *Pleopis polyphemoides*; *Podon intermedius* and *Acartia tonsa*) during the winter and spring, which are characterized by the presence of the Subtropical Shelf Front and by processes of upwelling or inflow of the SACW. These processes increase the diversity of indicator species of waters of different origins, and indicate that the coast is an area of transition between the tropical, subtropical and temperate faunas between the south and southeast regions of Brazil. However, the lack of information for the extreme south of the state points to the existence of a gap in knowledge and the small number of samplings around the area of upwelling of Santa Marta Cape.

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RESUMO

Este trabalho apresentada informações oriundas de diferentes amostragens realizadas ao longo da costa de Santa Catarina com o objetivo de esboçar as características biogeográficas do zooplâncton assim como identificar espécies ou grupos de espécies com potencial uso como bioindicadores. A partir de um *cheklist* das espécies da comunidade zooplanctônica do estado observou-se que nos meses quentes do ano a fauna é similar aos dos estados do Paraná e São Paulo (e.g. *Creseis virgula* f. *virgula*, *Penilia avirostris*; *Acartia lilljeborgi* e *Oithona oswaldocruzi*), enquanto que nos meses frios, apresenta representantes costeiros da fauna do Rio Grande do Sul (e.g. *Acartia tonsa*). Entretanto, o zooplâncton é dominantemente termófilo na maior parte do ano, típico da Água Tropical de Plataforma. Existem diversas espécies do zooplâncton que podem ser utilizadas como indicadoras hidrológicas, permitindo diferenciar águas costeiras sob influência de aportes continentais (e.g. *Paracalanus quasimodo* e *Parvocalanus crassirostris*), comuns no norte do estado, e de processos de ressurgências (e.g. *Podon intermedius*) e da influência da Frente do Prata originárias do sul (e.g. *Pleopis polyphemoides*). Os diferentes ambientes investigados apresentam uma abundância do zooplâncton dependente da influência de aportes continentais e da possibilidade de sua retenção e aproveitamento do enriquecimento costeiro que variam sazonalmente.

Palavras-chave: bioindicadores, *cheklist*, espécies costeiras, massas de água, ambientes costeiros, biogeografia.

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